



Assessment Of Particulate Matter And Other Pollutants In Urban Areas Of Tirupati, Andhra Pradesh, India

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Abstract

Air pollution is defined as the presence of dangerous or excessive amounts of pollutants in the Earth's atmosphere. These compounds, known as pollutants, can be naturally occurring or man-made, and they can harm human health, the environment, and the climate. There are many different sources of air pollution, including industrial operations, vehicular emissions, etc. Particulate Matter (PM), carbon monoxide (CO), Nitrogen oxides (NO_x), Sulphur oxides (SO_x), volatile organic compounds (VOCs), and Ozone (O₃) are examples of common pollutants. Tirupati which is a pilgrimage city along with its increasing population these two substantial increases in levels of pollution in the air. Four sampling sites are selected for analysis, i.e. Regional Science Centre, Municipal Office, Tirupati, APPCB, RO, Tirupati, S.V.U Guest House, Tirupati. The pollutants data were obtained from the APPCB Office and the pollutants were analyzed through a Respirable Dust Sampler (RDS). This study quantifies various pollutants and Particulate Matter concentrations present in Tirupati city which also focuses upon in and around the city. In the present work, four regions were selected that specify the variations. Here, PM concentrations according to different seasons i.e. Summer (April-June), Monsoon (August and September), and Winter (December to February) are discussed. Results are based on reports of two years 2021-22. The importance of this work is to summarise the data on Air pollution in Tirupati city, which is also one of the world's biggest pilgrimage sites.

Keywords - Air Pollution, Particulate Matter, Pollutants, Respirable Dust Sampler.

I.INTRODUCTION

The adverse consequences of air pollution on human health, ecosystems, and the economy make it a major global environmental and public health concern [1]. Low air quality is mostly caused by various air pollutants and respirable particulate matter (PM_{2.5} and PM₁₀). Particulate matter with aerodynamic dimensions of less than 2.5 micrometres and 10 micrometres is referred to as PM_{2.5} and PM₁₀, respectively. These particles can be extremely harmful to one's health if they are breathed into the respiratory system. They come from both natural and man-made sources. Other air pollutants that are frequently measured and controlled include heavy metals including lead, mercury, and arsenic, as well as nitrogen dioxide (NO₂), sulphur dioxide (SO₂), ozone (O₃), carbon monoxide (CO), and volatile organic compounds (VOCs). In addition to natural sources like volcanic eruptions and wildfires, these pollutants are produced by combustion processes, industrial operations, vehicle emissions, and agricultural practices. Particulate matter and other air pollutants can cause a variety of harmful health outcomes, such as lung cancer, respiratory and cardiovascular disorders, attacks of asthma, and early mortality[3,6]. Air pollution has negative effects on human health in addition to negative effects on the environment, such as acid deposition, eutrophication of water bodies, harm to plants, and

ecosystem deterioration [4]. A multifaceted strategy including governmental regulations, technology developments, public awareness campaigns, and international collaboration is needed to address air pollution. Implementing emission regulations, embracing greener technology, encouraging renewable energy sources, enhancing monitoring and modelling capabilities, and improving transportation and urban planning are some strategies for reducing air pollution. To promote sustainable growth, maintain public health, and protect the environment, effective air quality management necessitates ongoing particulate matter and other pollution monitoring assessment, and regulation. These particles could contain a variety of airborne pollutants, allergies, or other dangerous materials. A Respirable dust sampler's main function is to measure the amount of airborne particulate matter in a given space, like an outdoor area or workplace, to determine the possible health hazards to anyone who may be exposed to these particles. Indian mega cities rank among the most polluted in the world [5]. The composition of ambient air particulate matter is complicated and varies according to source and location [7]. Several research investigations over the last decade have found links between air pollution and negative human health effects, and each pollutant has its unique health risk profile [8]. The quantity of particulate matter and gaseous contaminants in the air affects the quality of the air we breathe. Periodic measurements of hazardous contaminants in ambient air quality are crucial [9]. According to the World Health Organisation (1999), Air Pollutants are substances that humans release into the atmosphere at levels high enough to endanger human health, vegetation, and property, or interfere with one's ability to enjoy their property [10]. Temple town Tirupati located in Andhra Pradesh, India attracts every month, an estimated 1,40,000 automobiles and approximately 1.5 million devotees. Further, the economic development of Tirupati has been very rapid in recent years as a result of industrialization, automobile growth, and urbanization. These developments continuously put enormous stress on the air quality management of the city. Today's air quality in metropolitan areas and cities is considerably different from that of natural air quality a few years ago [2]. We have chosen four distinct Tirupati sample sites for this investigation. The sampling process consists of a Bi-Annual Report for 2021-2022. An estimate was made of the following: respirable suspended particulate matter (PM_{10}), particulate matter ($PM_{2.5}$), sulphur dioxide (SO_2), nitrogen oxides (NO_x), and ammonia (NH_3).



II. MEASUREMENT SITES, MEASUREMENTS AND METHODOLOGY

2.1 Measurement sites

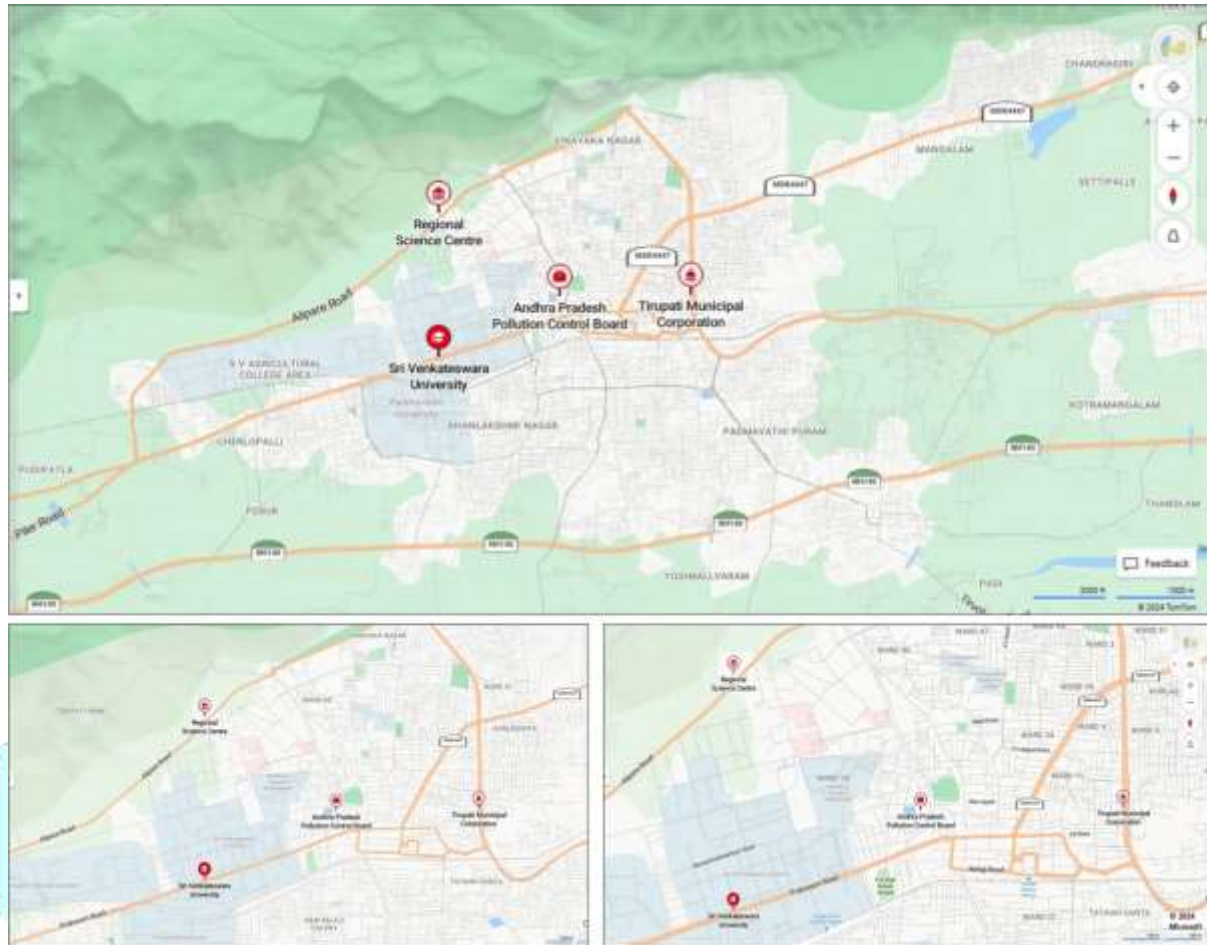


Figure 1. Location Map of Tirupati region showing sampling sites in Andhra Pradesh, India. [12]

We collected the data from the Andhra Pradesh State Pollution Control Board (APPCB), Tirupati, Regional Office Lab. The Samples are analyzed by a Respirable Dust Sampler (Envirotech APM 460). It is a tool used to gather dust particles in the air that people may breathe in. 753,000 people live in Tirupati according to the 2023 census, 3.29% more than in 2022. We have chosen four areas that can be classified based on urbanization, vehicle emissions, and plantation. Among our four regions, two of them are suburban sites close to the Tirumala hill forest, and two other sites are located within the city and experience heavy day-to-day traffic.

Regional Science Centre, Tirupati: (13.64491 N, 79.39812 E):

Regional Science Centre (RSCT) is situated at the foothills of Tirumala, on Alipiri-Zoo Park Road. It is just below the Tirumala forest region. The entire area abounded in vegetation. Many people visit here for tourist and educational purposes. Compared to the city the traffic and other urban influence is significantly low here.

Municipal Office, Tirupati: (13.63510 N, 79.42374 E):

Located in Tirupati's south-central region. It is a crowded city region with residential buildings, and business complexes, hotels, and restaurants, private travel offices, consultancies. The main market of Tirupati is also nearby which is crowded always. The Andhra Pradesh State Transport Corporation (APSRTC) bus terminal is located roughly 500 feet away from the location.

APPCB, RO, Tirupati: (13.63307 N, 79.41062 E):

It is located on Narasimha Teertham Road Tirupati, which is located to the northeast of S.V. Arts College, sharing boundaries with the National Sanskrit University. Also, it is a semi-urban site with a significant

amount of trees and plants away from busy city traffic. Domestic activities such as firewood burning, and waste burning are often observed.

S.V.U Guest House, Tirupati (13.62450 N, 79.39446 E):

Located near S.V. University beside the flyover over of NH-5 close to the busy traffic. This site is also surrounded by university campus trees. Highways are the main emission source also with the university traffic during the day time. Along with highway traffic, domestic wood and waste-burning activities have also been observed. Studies data were taken according to different seasons i.e. Summer (March-May), Monsoon (July-September), and Winter (November-January). The months of Feb, Jun and Oct are observed to be transitional times because of their generally consistent weather and sunny days. In terms of geography, Tirupati receives significant amounts of rainfall anytime there are cyclonic developments in the Bay of Bengal, off the coast of Chennai and coastal Nellore, due to its proximity to these coastal districts. Because of this, this region receives abundant rains from both the North-East monsoon and the South-west monsoon. For two years (Jan 2021-Dec 2022), studies were observed monthly in the current analysis to provide an in-depth picture of monthly and seasonal variations in pollutant concentrations.

2.2 Measurements and Methodology

Experiments were performed by the Andhra Pradesh State Pollution Control Board, Tirupati Regional Office Lab. The PM_{2.5} and PM₁₀ are collected by a Respirable Dust Sampler (Envirotech APM 460). It is a tool used to gather dust particles in the air that people may breathe in. A glass fibre filter paper measuring 20.3 × 25.4cm (8×10 in) is used to collect PM₁₀ and PM_{2.5} in air through a size-selective intake. 1.18 m³ of air suction flow per minute on average was used to run the sampler. The difference noted between the filter weights before and after sampling yields the mass of these particles. The weight gain of the filter is divided by the volume of air measured to determine the quantity of suspended particulate matter in the specified size range.

Volume of the Air sample is calculated by the Formula

$$V = QT = \frac{(F_i + F_f)}{2} \times t_s \times 10^{-6}$$

V = Volume of sampled air in m³

Q = Average flow rate in m³/min

T = total sampling time in min

F_i = Air flow rate before sampling (cm³/min)

F_f = Air flow rate after sampling (cm³/min)

t_s = Sampling time

10⁻⁶ = Conversion of cm³ to m³

Calculation of PM₁₀ and PM_{2.5} in ambient air:

$$PM_{10} = \frac{(W_p + W_f) - (W_i + W_j)}{V} \times 10^6$$

$$PM_{2.5} = \frac{(W_p + W_f) - (W_i + W_j)}{V} \times 10^6$$

W_p = Weight of material that was collected on weighing paper, in gm

W_j = Initial weight of weighing paper, in gm

W_f = Exposed filter weight, in gm

W_i = Tare weight of the filter, gm

With the aid of the accessories that came with the sampler, the same sampler was used to sample NO₂ and SO₂. Sampling was completed over 24 hours on the same day. 30ml of absorbing solutions were placed in standard impingers that were attached to the sampling tube to sample SO₂ and NO₂. The modified West and Geake method was used to analyze SO₂, and the modified Jacob and Hochheiser method was used to study NO₂. NH₃ is analyzed using the Indophenol method.

Calculation of NO₂ concentration in ambient air

NO₂⁻ is calculated as µg/m³ by the equation

$$\mu\text{g (NO}_2^-)/\text{m}^3 = \frac{\mu\text{g (NO}_2^-) \times V_s}{V_a \times 0.82 \times V_t} \times D$$

µg (NO₂⁻) = Concentration of NO₂⁻ in analyzed sample

V_a = Volume of air sample, m³

0.82 = sampling efficiency

D = Dilution factor (D=1 for no dilution; D=2 for 1:1 dilution)

V_s = Final volume

V_t = Aliquot taken for analysis

The NO₂⁻ concentration may be calculated as ppm using:

$$\text{ppm NO}_2^- = (\mu\text{g (NO}_2^-)/\text{m}^3) \times 5.32 \times 10^{-4}$$

The calculation of Concentration of SO₂ in µg/m³ in the ambient air sample is as follows

$$C (\text{SO}_2 \mu\text{g/m}^3) = \frac{(A - A_0) \times B \times 10^3}{V}$$

A = Sample absorbance

A₀ = Reagent blank absorbance

10³ = Conversion liters to cubic meters

B = calibration factor, µg/absorbance

V = volume of air sampled in litres

The SO₂ may be calculated as ppm as follows

$$\text{ppm(SO}_2) = \mu\text{g(SO}_2)/\text{m}^3 \times 3.82 \times 10^{-4}$$

Calculation of NH₃ concentration in ambient air

NH₃ is calculated as µg/m³ by equation

$$C (\text{NH}_3 \mu\text{g/m}^3) = \frac{A_s - A_b \times CF \times V_s}{V_a \times V_t}$$

CNH₃ = Concentration of Ammonia in µg/m³

A_s = Absorbance of sample

A_b = Absorbance of reagent blank

CF = Calibration factor

V_a = Volume of air sample in m³

V_s = Final volume of the sample in ml

V_t = Volume of the aliquot taken for analysis, ml

III. RESULTS AND DISCUSSIONS

The average monthly and seasonal variation of SO₂, NO₂, NH₃, PM₁₀, and PM_{2.5} are shown graphically.

3.1 Seasonal variations

Among the above-mentioned four areas, two of them (The municipal office, and APPCB regional office) showed higher pollutant concentrations (Tables 1-2) than the remaining two areas (Regional Science Centre and SVU guest house). The PM₁₀ concentrations in the first set of regions were nearly 20-30% higher than in the second set of regions during summer. Whereas in winter there is an increase in PM₁₀ concentrations in all regions when compared to summer. Among them, the Municipal office region is the most polluted in two years in all seasons. After that S.V.U region shows greater concentrations of PM₁₀, following that regional science center and APPCB show lower concentrations. The increase in PM₁₀ is mainly due to heavy vehicle emissions, the highly polluted areas are due to continuous transportation in these regions. As said before municipal office has the main bus depot nearby whereas the S.V.U guest house is located beside the national highway and also the railway track near it. Interestingly in the case of PM_{2.5}, only two areas show them as pollutants according to our results. The municipal office and APPCB regional office areas show low concentrations of PM_{2.5} whereas the regional science centre and S.V.U guest house don't show any amount of PM_{2.5}. Similarly, in the case of gases, SO₂ was the same with slight differences in four regions. There is an increase of SO₂ in 2022 when compared to 2021 which shows a gradual increase of pollutants yearly. There is a spanning increase in Sulphur dioxide content in the monsoon season when compared to other seasons. Now taking NO₂ into account, is lower in the regional science center and APPCB whereas higher in the municipal office region especially in two summers. NH₃ seems to overall a major pollutant in all regions seasonally.

Table 1. List of pollutants in Tirupati area:2021

S.NO	Location Name	parameters (µg/m3)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Polluted areas														
1	Municipal Office, Tirupati	SO ₂	4.6	4.5	4.8	5.0	4.9	4.8	5.1	5.2	5.7	5.4	5.6	5.4
		NO ₂	9.6	9.4	9.7	10.5	10.1	10.8	14.1	15	16.6	17.8	14.7	14.4
		NH ₃	23.8	24.1	24.6	24.7	24.4	24.2	24.6	24.4	25.4	25	23.3	24.2
		PM ₁₀	41	42	45	45	44	52	57	52	57	62	68	57
		PM _{2.5}	14	16	18	19	18	20	22	22	24	26	19	18
2	APPCB, RO, Tirupati	SO ₂	4.4	4.5	4.7	4.8	4.6	4.9	5.1	5.0	5.1	4.7	4.9	4.8
		NO ₂	9.4	9.6	9.7	10.0	9.5	10.3	12.1	14.0	15.1	14.7	12	12.8
		NH ₃	22.6	23.2	23.3	23.1	23.9	23.0	23.0	22.8	23.4	24	22.8	23.1
		PM ₁₀	34	33	38	39	41	45	44	42	47	53	61	50
		PM _{2.5}	13	14	16	17	16	18	19	18	19	22	18	17
Less polluted Areas														
3	Regional Science Centre, Tirupati	SO ₂	4.4	4.5	4.4	4.5	4.4	4.5	4.7	4.6	4.7	4.6	4.9	4.6
		NO ₂	9.5	9.6	9.4	9.8	9.5	10.0	11.4	12.3	12.8	12.7	11.3	11.9
		NH ₃	23.0	22.9	21.9	22.5	23.6	22.7	22.8	22.8	22.8	22.9	22.4	22.3
		PM ₁₀	31	34	36	35	38	41	43	40	44	45	52	49
		PM _{2.5}	—	—	—	—	—	—	—	—	—	—	—	—

4	S.V Guest House, Tirupati	SO ₂	4.6	4.7	4.8	4.9	5.0	4.8	5.2	5.2	5.5	5.4	5.2	5.1
		NO ₂	9.7	9.6	9.9	10.2	10.0	10.9	14.2	14.2	15.7	16.6	13.1	13.6
		NH ₃	23.6	23.4	23.5	24.2	24.3	23.5	23.8	24.6	25	25.4	22.8	24.1
		PM ₁₀	39	37	44	46	50	51	53	48	53	58	62	56
		PM _{2.5}	–	–	–	–	–	–	–	–	–	–	–	–

Table 2. List of pollutants in Tirupati area:2022

S.NO	Location Name	parameters (µg/m3)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Polluted areas														
1	Municipal Office, Tirupati	SO ₂	5.2	5.0	5.2	5.3	5.4	5.3	5.5	5.4	5.6	5.8	4.9	5.0
		NO ₂	13.2	13.4	14.8	15.3	15.6	15.9	16.3	13.8	15.8	16.7	13.9	13.7
		NH ₃	24.1	24.2	24.2	26.8	24.7	24.6	24.4	24.9	24.8	24.3	24.9	24
		PM ₁₀	59	54	57	58	56	59	54	56	61	60	48	49
		PM _{2.5}	22.0	21	22	25	19	24	21	17	23	19	13	14
2	APPCB, RO, Tirupati	SO ₂	5.0	4.6	4.8	4.8	4.9	4.8	4.9	5.1	5	5.2	4.8	4.8
		NO ₂	12.4	11.5	12.4	12.2	14.1	13.8	13.2	12.1	14.1	14.4	13.2	12.5
		NH ₃	23.1	23.2	22.9	23.0	23.2	23.8	23.8	23.7	23.5	23.3	23.4	23
		PM ₁₀	53	48	50	51	49	45	44	45	52	54	40	41
		PM _{2.5}	19	17	20	21	17	18	17	14	19	17	12	13
Less polluted Areas														
3	Regional Science Centre, Tirupati	SO ₂	4.5	4.4	4.6	4.5	4.6	4.5	4.4	4.5	4.7	4.8	4.6	4.6
		NO ₂	12.1	10.7	11.3	11.1	12.1	11.9	11.3	11.2	12.8	12.7	12.0	11.4
		NH ₃	22.6	22.3	22.6	22.9	22.8	23	24.4	22.7	23.2	22.5	22.9	22.3
		PM ₁₀	50	42	45	44	41	39	37	36	41	39	34	37
		PM _{2.5}	–	–	–	–	–	–	–	–	–	–	–	–
4	S.V Guest House, Tirupati	SO ₂	5.1	4.9	5.1	4.8	5.1	5.4	5.1	5.3	5.7	5.7	5.2	4.9
		NO ₂	13.9	13.1	13.2	13.9	14.9	15.4	14.6	13.8	15.6	15.8	14	13.1
		NH ₃	23.2	23.7	23.8	23.7	23.8	23.9	23.4	24.6	23.5	24.2	24	23.7
		PM ₁₀	56	52	54	56	52	55	54	53	57	59	44	46
		PM _{2.5}	–	–	–	–	–	–	–	–	–	–	–	–



Figure 1. Graphs showing the list of Pollutants in Tirupati area:2021-2022

3.2 Monthly average variations

According to monthly average variation results of NO₂, NH₃, PM_{2.5}, and PM₁₀ pollutants among the four regions, especially in July. Pollutant concentrations are also affected by various reasons like seasonal festivals, and religious occasions. For example, every year in September or October major Hindu festivals occur like Dussehra, Diwali, etc., and also in these months, Brahmotsavams occur which is similar to Khumbmela. Millions of people from all over the country visit during this period which leads to subsequent increasing.

Table 3. Revised National Ambient Air Quality Standards (NAAQS), according to Central Pollution Control Board, India

S.No	Pollutants (µg/m ³)	Time Weighted Average	Concentration in Ambient Air		Methods of Measurement
			Industrial, residential, rural and other Areas	Ecologically Sensitive area (notified by the Indian government)	
1	SO ₂	Annual*	50	20	1. Improved West and Gaeke 2. Ultraviolet Fluorescence
		24 Hours**	80	80	
2	NO ₂	Annual*	40	30	1. Modified Jacob & Hochhesier 2. Chemiluminescence
		24 Hours**	80	80	
3	NH ₃	Annual*	100	100	1. Chemiluminescence 2. Indophenol method
		24 Hours**	400	400	
4	PM ₁₀	Annual*	60	60	1. Gravimetric 2. TEOM 3. Beta attenuation
		24 Hours**	100	100	
5	PM _{2.5}	Annual*	40	40	1. Gravimetric 2. TEOM 3. Beta attenuation
		24 Hours**	60	60	

*Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals. **24 hourly 08 hourly or 01 hourly monitored values, as applicable shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

transportation facilities. Hence, there will rise in air pollutants concentration in and across the city. According to our graphical data, we can also observe that various pollutants in different regions are based on their economic and geographical factors. For example, the concentration of PM_{2.5} (which is indicated as a line in the graph) is found only in the Municipal office region, and APPCB regional office area. Whereas in the Regional Science Centre and S.V.U guest house, PM_{2.5} is found to be nil. Due to this reason, these areas are surrounded by dense plantations and are closely located in the forest region. We also discussed the concentrations of our pollutants with the National Ambient Air Quality Standards (NAAQS) Table 3. produced by Central Pollution Control Board India. SO₂, NO₂, and NH₃ concentrations are very much low when compared to regulatory concentrations. Whereas concentrations of PM₁₀ and PM_{2.5} need to be considered when compared to other pollutants. Because levels of PM_{2.5} is found to be rising every year although PM_{2.5} is found only in two regions. Coming to PM₁₀ can be considered the most emerging pollutant though even its concentrations are still within limits. In September 2022, the months of October and November 2021 we can see its highest values of 60, 61, and 62 respectively. According to the Central Pollution Control Board concentrations of PM₁₀ must be below 60 µg/m³. Due to the reason of increase in transportation in those months as we discussed earlier, there is a rise in concentration levels. In further these values may increase more subsequently. An increase in population is also a factor for increasing pollution based on our results we can observe that in populated areas there is an increase in the concentration of pollutants. High pollution levels are constantly present among locals, merchants, traffic police, shopkeepers, tour guides, and others. Asthma, cancer, and other serious and chronic illnesses are among the minor health concerns associated with occupational hazards, which can include minor nasal irritation, burning in the eyes,

and other allergies [11]. The semi-arid area of Tirupati has hot, dry winds in the summer that originate in the arid North and North-west of India. These winds add to the season's increase in pollutant concentrations and moisture loss. The following climatic factors showed a significant degree of connection with pollutants: temperature, relative humidity, rainfall, and wind speed.

Conclusion

Air pollution has significant effects on human health, the environment, and climate change, making it a persistent global concern. Pollutants like sulphur dioxide, nitrogen dioxide, particulate matter, and volatile organic compounds are ubiquitous and provide serious obstacles to sustainable development and the health of present and future generations. It is commonly known that air pollution hurts cardiovascular and respiratory health, which raises rates of morbidity and death. People who are already vulnerable, such as children, the elderly, and those with pre-existing medical disorders, are especially vulnerable. Moreover, because some pollutants behave as greenhouse gases and affect weather patterns and global temperatures, air pollution exacerbates climate change. Overall, it was discovered that there was a strong correlation between the contaminants mentioned above. In conclusion, Municipal Office Tirupati is a highly polluted area when compared to the other three areas due to the rapid growth of urbanisation. The results of the study will assist the relevant authorities in creating better living conditions for both the residents and the pilgrims.

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